embodiments as follows. The concept of creating a local blocking region via fluorine implantation can be implemented in device structures that typically employ blocking structures, such as in an AlGaN/GaN vertical heterostructure field-effect transistors (V-HFET). While V-HFET implementations have typically used Magnesium (Mg) implantation followed by an expensive re-growth process, as described above, the provided structures and devices can be created by selectively implanting fluorine ions in developing structures (e.g., post-epitaxial growth).

[0130] FIGS. **43** to **44** depict a cross section of an exemplary non-limiting AlGaN/GaN vertical heterostructure field-effect transistor **4300** and **4400** with a fluorine implanted source-drain blocking region or layer according to various aspects of the disclosed subject matter. Advantageously, the described fluorine ion implantation operation is made available by commercial ion implantation providers, and the provided structures and devices can be created by selectively implanting fluorine ions in developing structures (e.g., post-epitaxial growth), which can avoid the expensive re-growth process. The provided structures are expected to improve source-drain isolation in the off-state by virtue of a fluorine implanted blocking region or layer.

[0131] FIG. **43** depicts an AlGaN/GaN V-HFET **4300** comprised of a substrate **4302**, upon which heavily doped GaN (N^+-GaN) **4304**, GaN (N^--GaN) **4306**, and an i-GaN/AlGaN (**1608**/**1610**) heterojunction is formed creating the 2DEG **4312** channel. Fluorine ions can be implanted to create the fluorine implanted blocking region or layers **4314**, which can serve to improve source **4316** to drain **4318** isolation in the off-state of the AlGaN/GaN V-HFET **4300**. The arrows traveling from the source pads **4316** through 2DEG **4312** around blocking layers or regions **4314** to the drain pads **4318** in FIGS. **43** and **44** are intended to indicate the expected electron flow as a result of the fluorine implanted blocking regions or layers **4314**, according to various aspects of the disclosed subject matter.

[0132] As described above, similar to the discussion regarding fluorine concentration in reference to FIGS. **2**, **3**, **22**, **19**, **37**, and **39**, although the fluorine implanted blocking region or layer **4314** in FIG. **43** is depicted as a discretely and homogenously shaded region to indicate the presence of the implanted fluorine concentration, the actual concentration profile, according to various embodiments, can be a continuum of fluorine concentrations in the fluorine implanted blocking region or layer **4314**, similar to that shown (although not necessarily the same concentration, position, dose, etc.) and described with reference to FIGS. **3** and **22**. For example, the blocking region or layer **4314** of **4300** is more accurately depicted as a continuum or gradient of fluorine concentrations in the blocking region or layer **4314** in **4400** of FIG. **44**, rather than as sub-regions of discrete concentrations.

[0133] Additionally, while the 2DEG Channel **4312** is depicted as a discrete region adjacent to and between the AlGaN layer **4310** and the i-GaN layer **4306**, 2DEG Channel **4312** is comprised of a narrower-bandgap channel at the heterojunction created due to the different band-gap materials forming an electron potential well in the conduction band on the non-doped side of the heterojunction.

[0134] Moreover, the ion energy and dose, as well as location, concentration profile, etc. as further described above, of the blocking region or layer **4314** can be adjusted for different requirements of the fluorine distribution. Accordingly, such embodiments should not be limited by any of the other exemplary non-limiting embodiments as described herein.

[0135] In view of the structures and devices described supra, methodologies that can be implemented in accordance with the disclosed subject matter will be better appreciated with reference to the flowchart of FIG. **45**. While for purposes of simplicity of explanation, the methodologies are shown and described as a series of blocks, it is to be understood and appreciated that such illustrations or corresponding descriptions are not limited by the order of the blocks, as some blocks may occur in different orders and/or concurrently with other blocks from what is depicted and described herein. Any non-sequential, or branched, flow illustrated via a flowchart should be understood to indicate that various other branches, flow paths, and orders of the blocks, can be implemented which achieve the same or a similar result. Moreover, not all illustrated blocks may be required to implement the methodologies described hereinafter.

Exemplary Methodologies

[0136] FIG. **45** depicts exemplary non-limiting methodologies for forming a back barrier region in a high electron mobility transistor (e.g., an EBB AlGaN/GaN HEMT **204**, **1800**, **1900**, **3600**, **3700**, **3900**, **4000**, **4100**, **4200**, **4300**, etc.) in accordance with aspects of the disclosed subject matter. As can be appreciated, variations in the exemplary methodologies known to one having ordinary skill in the art may be possible without deviating from the intended scope of the subject matter as claimed.

[0137] For instance, at **4502**, a buffer layer (e.g., **104**) can be deposited over a suitable substrate (e.g., **102**). For example, as described above, suitable substrates can comprise sapphire, silicon (111), silicon carbide, aluminum nitride (AlN), or GaN, or any combination thereof and can include a nucleation layer comprised of GaN or AlN to facilitate epitaxial crystal growth of the buffer layer. As a further example, the buffer layer **104** (e.g., unintentionally doped GaN) can be grown through an epitaxial crystal growth method (e.g., MOCVD, MBE, etc.).

[0138] Likewise, at **4504**, a barrier layer (e.g., **106**) can be deposited over the buffer layer **104** to form a heterojunction at the interface with barrier layer **106** and the buffer layer **104**. As with the buffer layer **104**, the barrier layer **106** (e.g., AlGaN) can be grown through an epitaxial crystal growth method (e.g., MOCVD, MBE, etc.).

[0139] In one non-limiting embodiment of the disclosed subject matter, the heterostructure can comprise 2 μm of unintentionally doped GaN (i-GaN) buffer layer **104** grown on a common substrate **102** of sapphire, upon which is grown a 24 nm barrier layer **106** of unintentionally doped AlGaN (i-AlGaN) (e.g., i-$Al_{0.25}Ga_{0.75}N$).

[0140] At **4506**, a back barrier region or layer **206** can be formed by implanting fluorine ions into the buffer layer **104**. For example, the fluorine ions can be implanted under the design or prospective location for the heterostructure gate **210**, during the HEMT fabrication process post-growth, and in some cases, before further processing continues. This location for implantation is chosen as gate **210** is typically fabricated at a later step (not shown), which according to various aspects of the disclosed subject matter, is to be located substantially over the back barrier region or layer **206** (e.g., an enhanced back barrier in accordance with the disclosed subject matter).